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Revision of anterior cruciate ligament reconstruction with allografts in patients younger than 40 years old: a 2 to 4 year results

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Abstract
Purpose The purpose of this study is first to report the outcomes, at 4 years follow-up, in revision ACL surgery using allografts in patients younger than 40 years old, and then compared soft tissue allografts to bone tendon allografts.
Methods This retrospective study included 47 patients who underwent ACL revision surgery with fresh-frozen allografts. Patellar tendon allograft or tibialis anterior allograft was used. Twenty-seven patients undergoing ACL revision with patellar tendon allograft were compared retrospectively with twenty-two patients undergoing the same procedure with soft tissue tibialis anterior allograft. Lysholm, IKDC, and KT-1000 values were obtained preoperatively and postoperatively.
Results The average patient follow-up was 4.6 years (±2.5). The mean age at time of the revision was 34 years old (±6.3). Overall, patients reported the overall condition of their knee as excellent or good in 85 % of the patients (10 excellent, 33 good). Based on their experience, 85 % would have the surgery again if they had the same problem in the other knee. Both subgroups experienced significant improvement in Lysholm, IKDC, and KT-1000 values, with no difference found between groups at final follow-up.
Conclusion Revision ACL with allografts has excellent and good results in 85 % of patients younger than 40 years old. No statistical difference was seen between soft tissue (tibialis anterior) and patellar tendon allograft.
Level of evidence IV.

Keywords ACL revision · Allografts · Knee

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Introduction

As the number of ACL reconstructions performed each year continues to rise, so does the number of revision surgeries. Allografts are a tempting alternative in revision ACL surgery. No donor morbidity, tissue availability and decrease operation time with smaller incisions are the main advantages of using allografts. However, some orthopaedics surgeons may argue allografts are not the best graft option in young and active patients, suggesting higher rate of failure when compared to autografts [2, 6, 16].

Multiples graft options can be considered in a revision ACL reconstruction scenario [15, 19]. These include contralateral and ipsilateral hamstring, patellar tendon and quadriceps tendon autografts, and a variety of allografts. Graft choice is predominantly influenced by two factors: previous graft(s) used and surgeon's preference. Other factors that should be considered include patient's preference, age, gender, level of activity and contralateral knee status.

Graft tissue that is typically used for ACL allografts reconstructions includes bone–patellar tendon constructs, as well as soft tissue grafts such as semitendinosus, Achilles, or anterior tibialis tendons. Although bone–patellar tendon–bone (BPTB) allografts have the advantage of high initial fixation strength with early bone-to-bone healing, they have a considerably lower availability in tissue banks compared with soft tissue ACL allografts. In addition, the length of BPTB allografts must match closely with the recipient to avoid graft-tunnel length mismatch. Because of these limitations, soft tissue allografts are emerging as a popular choice for ACL reconstruction [4].

Although the clinical outcomes of soft tissue and bone tendon grafts are comparable [1, 20], the rates and characteristics of the healing processes among grafts differ. Compared to BTB, soft tissue grafts showed a slower incorporation rate into the bone tunnel [18]. Incorporation time may also differ between allograft and autograft. Delayed incorporation of the graft has been agreed on disadvantage of allografts. Several studies have shown a slower rate of biological healing and less strength of the reconstruction at early time points [9, 14].

Clinical outcomes of ACL revision procedures comparing soft tissue allograft and bone tendon allograft have not been widely studied. Determining whether similar outcomes are obtained with either allograft would help the orthopaedic surgeon decide according to factors such as availability, patient's request or preferable technique rather than graft behaviour.

The purpose of this study is first to report the experience at the Hospital Italiano de Buenos Aires, with revision ACL reconstruction surgery using allografts in patients younger than 40 years old, then compare those patients treated with tibialis anterior allograft (soft tissue grafts) to those with patellar tendon allograft (bone tendon grafts).

Materials and methods

A review of all operative records of attending surgeons during a 10-year period (1997–2007) revealed a total of 2,988 ACL reconstructions procedures, of which 89 (3 %) were classified as a revision surgery. From these 89, 42 were excluded: 18 had multiligament reconstruction, nine had contralateral limb surgery, three had concomitant osteotomy procedure, and 12 patients were lost to follow-up. The study included 47 patients. All patients were less than 40 years old. Seven were females and 40 were males. The mean age at time of the revision was 34 years old (±6.3). The mean time from the original knee surgery was 3 years (range 2 months–8 years). Mean follow-up was 4.6 years (±2.5).

Surgery was performed by two orthopaedic sports-trained surgeons. The primary ACL reconstruction graft choice included 23 hamstring autografts and 24 patellar tendon autografts. In all cases, interference screws were used for fixation in both tibia and femur tunnels. The mode of failure was determined for each case showing: traumatic for 33 patients (70 %), technical error in ten patients (21 %) and four patients (9 %) had arthrofibrosis. The type of technical failure was determined at the time of surgery by the surgeon using all available evidence (history, physical examination, radiographs, and arthroscopic evaluation). Surgeons were allowed to indicate more than one type of technical error. Femoral tunnel malposition was rated as the most common technical failure by far (70 %), followed by tibial tunnel malposition (20 %) and one posterolateral instability (10 %). All patients had a functional instability defined by the surgeon by either MRI, knee laxity (more than 5 mm side-to-side difference on KT 1000 testing), a positive pivot-shift or Lachman test, functional instability, and or by arthroscopic confirmation. The time from the last reconstruction was less than 1 year for 10 % (5 patients), between 1 and 2 years for 11 % (6 patients), between 2 and 4 years for 45 % (21 patients), and more than 5 years for 34 % (15 patients).

Before the surgery, MRI and radiograph were performed to assess tunnel location, widened, and associated lesions. All allografts were fresh-frozen, non-irradiated. Patients were treated with patellar tendon bone allograft or with tibialis anterior allograft. Selection of one or either graft was performed according to graft availability at time of surgery. All tibialis anterior allografts were double strained and fixed with interference screw. Initially, a diagnostic arthroscopy was performed to assess associated lesions in the different compartments and condition of the previous ACL graft. In all cases, a notchplasty was performed to obtain an adequate visualization. Previous femoral bone tunnels was observed and considered to be or not in the correct location. This was analysed before surgery with radiographs using the quadrant method on the sagittal view together with the clock system in the coronal view. Intra-operative the 'Clock Face system', the resident ridge and the lateral bifurcate ridge were also used. The posterior wall was also used to determine tunnel placement in the sagittal view. Ideally, bone tunnels should be located 4 mm away from the posterior wall. If the tunnels were considered to be in the desire location, the metallic previous hardware was removed and the tunnel was re-reamed. If previous hardware was re-absorbable screws, the tunnel was re-reamed directly. In those non-correct location tunnels, hardware from previous surgery was ignored, leaving the previous graft as an augmentation and drilling a complete new bone tunnels in the correct locations. In all cases, a transtibial technique was used. Bone grafting of dilated tunnels was performed at the time of the revision in three patients (1 for the tibia and 2 for the femur). All were performed as a one-staged procedure, at time of revision. Tibialis anterior allografts were fixed with 30 degree of flexion, applying posterior drawer and manual tension during tibia fixation. Patellar tendon allograft was fixed in 10 degree of knee flexion, with posterior drawer and manual tension as well.

Concomitant knee injury (meniscal and chondral) was common in this cohort. Previously treated meniscal injury was noted in 74 % of patients (33 patients). Articular cartilage damage grade 2 or worse using the modified Outerbridge classification system was noted in 70 % (32 patients). Both meniscal and articular cartilage damage were seen in 57 %. Only 10 % of the patients had neither meniscal nor articular cartilage damage at the time of the revision.

A knee brace locked in extension was used postoperatively for 6 weeks in all patients. Range of motion was allowed from 0 to 90 degrees. Partial weight bearing was indicated in the first 2 weeks and then gradually progress to full weight bearing. Stationary bicycle was allowed at 2 weeks and use of stair climbing machines was permitted at 4–6 week. Running was allowed at 3 months and contact sports at 8 months postoperative.

Outcomes were evaluated overall and then according to subgroups. Only patients with a minimum of 24-month follow-up were included for analysis. Follow-up examination was conducted by both a Sports Fellow and by the surgeon. Questionnaires were administered preoperatively, 6 months postoperatively, 1 year postoperatively, and then annually. Subjective measures were based on several scoring systems including Lysholm and IKDC. Patients were also asked to rate the overall condition of their knee at the time of the last follow-up: 0–2, poor (significant limitations that affect activities of daily living), 3–4, fair (moderate limitations that affect activities of daily living, no sports possible), 5–6 good, 8 very good (rate limitations, able to participate), and 9–10, excellent (able to do whatever I wish with no problems). Patient satisfaction with surgical outcome was elicited with the following scale: completely satisfied, mostly satisfied, somewhat satisfied, and unsatisfied. Finally, patients were asked if, based on their experience, they had the same problem in the opposite knee, would they have the surgery again.

Objectively, each knee was tested preoperatively and postoperatively with the KT-1000 arthrometer by an experienced independent examiner (A.M) evaluating anterior manual maximum, and manual maximum side-to-side differences were calculated. An arthrometric failure was defined as a side-to-side difference of 5 mm. Results were stratified into <3, 3–5 and >5 mm.

Patients were subcategorized in two subgroups. Those patients treated with bone patellar tendon allograft and those treated with a tibialis anterior allograft (Table 1). From the 47 patients, 25 patients treated with a bone–patellar tendon–bone allografts (Group PTG) and 22 were treated with tibialis anterior tendon allografts (Group TA). All patients treated with a patellar tendon allograft had a bioabsorbable interference screw fixation. Fifteen patients with tibialis tendon allograft had bioabsorbable interference screw fixation in both tibial and femoral tunnel. Seven had a femoral cross pin fixation and bioabsorbable interference screw tibia fixation.

Table 1 Demographic data from the subgroups

Patients characteristics for the different subgroups			*p* value
	Group PTG	Group TA	
Patients	25	22	n.s
Male/female	20/5	20/2	n.s
Age	29 (±7)	27(±6)	n.s
Time between surgeries (years)	4	3	n.s
Follow-up	4	3.3	n.s

PTG Patellar tendon allograft, *TA* tibialis anterior allograft, *N.S* non-significant

Complications were defined as any intervention not considered as post-operative standard care procedure or any event that required additional treatment. Failure was defined as persistent instability, graft re-rupture that required a re-revision.

This study protocol was approved by the institutional review board (IRB) of Hospital Italiano de Buenos Aires, Argentina (ID:11-3456).

Statistical analysis

Descriptive statistics were calculated according to standards methods, including frequencies, means, standard deviations, and ranges when appropriate. Clinical outcome scores were analysed at 2 time points: preoperatively and at the most recent follow-up. Score improvement was calculated using Mann–Whitney–Wilcoxon test. Factor analysis of type or procedure and time of follow-up was performed using Pearson correlation post hoc t testing. To achieve 80 % power with an effect size of 0.4 and α 0.05, 20 patients were required per group for an analysis of variance design. Subgroup analysis was performed using also an unpaired t test. Statistics were performed using GraphPad Software (GraphPad Software, La Jolla, CA) and the G* Power statistical program [7].

Results

The average patient follow-up was 4.6 years (±2.5). Patient reported the overall condition of their knee as excellent or good in 85 % of the patients (10 excellent, 33 very good) (Fig. 1). Based on their experience, 85 % would have the surgery again if they had the same problem in the other knee. Overall, statistically significant improvement (preoperative to postoperative) was seen in both Lysholm (61 ± 4.7–92 ± 4.0, $p < 0.05$) and subjective IKDC scores (31–57, $p < 0.05$). Objectively, 70 % scored A (thirty-three), 21 % (ten) B, 7 % C (three), and 2 % D (one) (Fig. 2). Preoperative KT 1000 examination was performed in all patients. The mean manual maximum translation was

4 mm (range 2–18 mm, SD ± 2.9) for the affected knee, and the mean maximum translation was 2.8 mm (range 2–10 mm, SD ± 1.4) for the unaffected knee. At time of last follow-up, KT 1000 translations were significantly reduced ($p < 0.05$) compared with their preoperative status. Thirty-eight patients (80 % or 38/47) had side-to-side difference <2 mm, and 8 patients (17 % or 8/47) had a side-to-side difference between 2 and 5 mm. Only one patient had a side-to-side difference >5 mm. Pivot-shift test revealed no pivot in 61 % patients (29/47), grade 1 in 23 % (11 patients), grade 2 in 12 % (6/47), and one patient with grade 3.

Analysis of subgroups

Subgroup analysis revealed no difference in patient age at implantation (n.s), gender (n.s). Both groups (patellar tendon group and tibialis anterior group) had significant improvements in Lysholm score (Fig. 3). No statistical difference was evident in the side-to-side KT 1000 arthrometric evaluation (Table Arthrometric Evaluation Subgroups). Difference in pivot-shift test among the subgroups is shown in Tables 2, 3.

Complications

There were no infections, no additional surgeries for arthrofibrosis, and no removal of hardware performed. There was no evidence of graft rejection or reabsortion or clinical evidence of graft insufficiency at the time of follow-up. Only one patient showed persistent instability after ACL revision surgery. A posterolateral corner insufficiency was diagnosed. Subsequent treatment included posterolateral corner reconstruction.

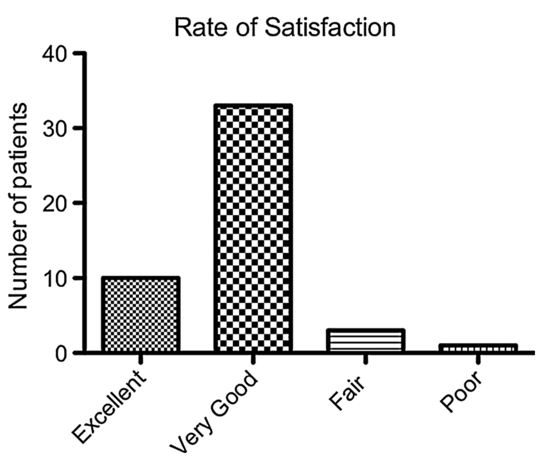

Fig. 1 Overall condition of the knee in patients undergoing revision ACL reconstruction surgery. 0–2, poor (significant limitations that affect activities of daily living), 3–4, fair (moderate limitations that affect activities of daily living, no sports possible), 5–8, very good (some limitations with sports, but I can participate), and 8–10, excellent (able to do whatever I wish with no problems)

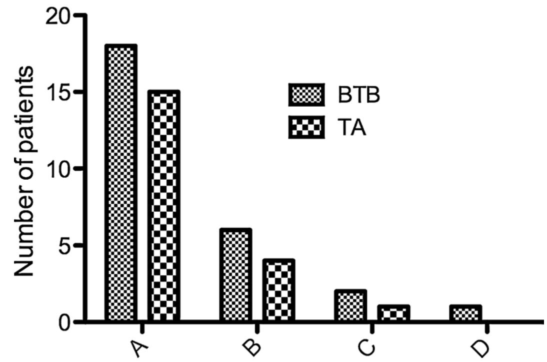

Fig. 2 Bar graph representation of postoperative IKDC in both BTB (bone patellar tendon bone allograft) and TA (tibialis anterior tendon allgraft). *A* normal, *B* almost normal, *C* abnormal, and *D* severely abnormal

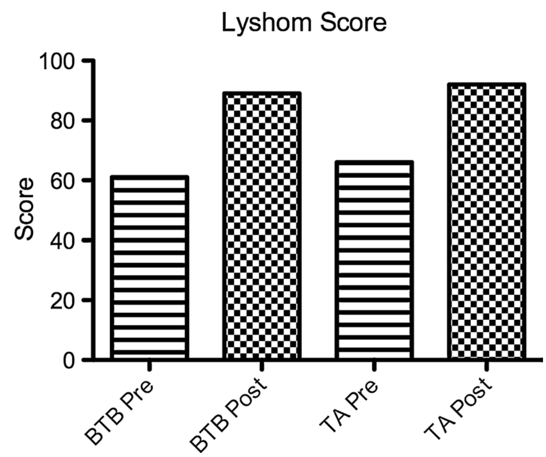

Fig. 3 *Bar graph* representation of preoperative and follow-up Lysholm score for both BTB(bone patellar tendon bone) and TA (Tibialis anterior tendon allograft)

Table 2 Overall and corresponding subgroups's maximum manual KT 1000

KT 1000	Translation side to side			Total of patients
	Less 2 mm	2–5 mm	More than 5 mm	
Overall	38	8	1	47
PTG	19	5	1	25
TA	19	3	0	22

Note overall, 38 patients or 81 % had a translation less than 2 mm. No statistical difference among subgroups

PTG patellar tendon allograft, *TA* tibial anterior tendon allograft

Discussion

The most important finding of the present study was first that revision ACL with allografts showed good clinical results in patients younger than 40 years old in 85 % of our patients. Secondly, no statistical difference was evident

Table 3 Overall and corresponding subgroups's pivot shift

Pivot-shift test	Grade 0	Grade 1	Grade 2	Grade 3	Total of patients
Overall	31	10	5	1	47
PTG (N)	16	6	2	1	25
TA (N)	13	5	4	0	22

Overall, 31/47 patients had no pivot shift or grade zero. No statistical difference among subgroups

PTG patellar tendon allograft, *TA* tibial anterior tendon allograft

between those patients treated with patellar tendon and tibialis anterior allograft.

Overall, results are similar to previous studies, with 85 % of patients satisfied with the procedure. Stability was achieved in 80 % of our patients (38 of 47) with an anterior translation less than 2 mm. Some studies have shown negative Lachman test results with allografts after 2 and 6 years [8]. A possible reason for this finding lies in the use of high-dose gamma irradiation for sterilization [17]. Kaminski et al. [10] carried out mechanical tests at baseline and concluded that adequate results can be achieved using deep-frozen transplants with additional irradiation. All allografts used in the present study were deep-frozen which could explain the good results in terms of stability.

Studies comparing allograft versus autograft in ACL surgery have been inconclusive. Some studies suggest that allograft ACL reconstructions have an increased failure rate especially in younger active patients compared to older less active patients [2, 5, 21]. Recently, Pallis et al. [16] reported survival comparison between allografts and autograft in reconstruction of ACL at the United States Military Academy. They showed that those young individuals who underwent an allograft ACL reconstruction were significantly more likely to experience clinical failure requiring revision reconstruction compared with those who underwent autologous graft reconstruction. Contrary, some controlled randomized studies have shown no difference in stability or subjective and functional outcomes when comparing allograft versus autografts from primary ACL reconstruction [11, 22]. Results from the present study suggest that allografts are a good option to consider in patients younger than 40 years old undergoing a revision ACL reconstruction with good outcomes at 4 years follow-up in 85 % of the patients.

In the current study, no difference was evident between BTB and soft tissue allograft. Results of different type of allografts (soft tissue versus bone tendon) in revision ACL surgery have not been studied. The Danish registry recently published interesting data about primary and revision ACL reconstructions. The 5-year re-revision rate was 5.4 %. Using allograft was a risk factor for re-revision. Type of allograft used for the revision was not informed [12].

Associated cartilage and meniscal lesions are also co-factors that should be considered in a revision ACL scenario as these patients have normally a worst prognosis. In the MARS ACL revision cohort, group, meniscal, and cartilage injuries were seen in 90 % of patients [13]. This is similar to *the current study* where 75 % of patients had associated cartilage or meniscal injuries. Unfortunately, patients with these associated lesions were not analysed separately. In the future, this subgroup should be considered separately as outcomes have shown patients do worst down the road with these associated lesions [23].

Revision procedures should be able to restore knee stability. Similar to previous published data [24], the present study objectively showed that anterior–posterior translation was re-established in 80 % of the patients with less than 2 mm side-to-side difference at time of follow-up. On the contrast, pivot shift could be eliminated only in 65 % of the patients. We believe that this could be explained to the femoral tunnel position, as at the time of the study, the femoral tunnel was still created transtibial. Pivot shift normally evaluates posterolateral bundle. This bundle is anatomical better reproduced using the anteromedial portal, which allows a more horizontal tunnel. All patients included in this study were treated with a transtibial technique [3].

Limitations in this study should be considered. First is a retrospective study. Secondly, the comparison between two groups (patellar bone tendon and allograft tibialis tendon) was limited to 25 and 22 patients in each corresponding subgroup, making the statistical background potentially weak. Third, those patients with associated cartilage and meniscal lesions at time of revision were not considered separately. Negative correlation between associated cartilage and meniscal injuries at the time of revision and subjective outcome has already been shown and should be considered in the future when analysing outcomes for ACL reconstruction.

Conclusion

This study suggests that allograft is a good graft choice in revision ACL reconstruction in patients younger than 40 years old. No difference was found between patellar bone tendon allograft versus tibialis anterior tendon. Comparison between these two groups (patellar bone tendon and allograft tibialis tendon) was limited making the statistical background potentially weak.

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